

industries employing the largest numbers of computer engineers in 1997 were:

Computer and office equipment	\$63,700
Measuring and controlling devices	62,000
Management and public relations	59,000
Computer and data processing services	56,700
Guided missiles, space vehicles, and parts	49,500

Median annual earnings of computer support specialists were \$37,120 in 1998. The middle 50 percent earned between \$28,880 and \$48,810. The lowest 10 percent earned less than \$22,930 and the highest 10 percent earned more than \$73,790. Median annual earnings in the industries employing the largest numbers of computer support specialists in 1997 were:

Management and public relations	\$37,900
Computer and data processing services	36,300
Computer and office equipment	36,300
Professional and commercial equipment	35,700
Personnel supply services	35,200

Median annual earnings of database administrators were \$47,980 in 1998. The middle 50 percent earned between \$36,440 and \$69,920. The lowest 10 percent earned less than \$28,320 and the highest 10 percent earned more than \$86,200. Median annual earnings of database administrators employed in computer and data processing services in 1997 were \$49,000.

Median annual earnings of all other computer scientists were \$46,670 in 1998. The middle 50 percent earned between \$34,290 and \$70,250. The lowest 10 percent earned less than \$26,690 and the highest 10 percent earned more than \$87,730. Median annual earnings of all other computer scientists employed in computer and data processing services were \$46,500 and in personnel supply services, \$33,600 in 1997.

Starting salaries for computer scientists or computer engineers with a bachelor's degree can be significantly higher than starting salaries of bachelor's degree graduates in many other fields. According to the National Association of Colleges and Employers, starting salary offers for graduates with a bachelor's degree in computer engineering averaged about \$45,700 in 1999; those with a master's degree, \$58,700. Starting offers for graduates with a bachelor's degree in computer science averaged about \$44,600; in computer programming, about \$40,800; in information sciences, about \$38,900; and in management information systems, \$41,800 in 1999. Offers for those with the bachelor's degree vary by functional area for all types of employers, as shown in the following tabulation.

Hardware design and development	\$45,900
Software design and development	45,600
Information systems	41,600
Systems analysis and design	41,100

Offers for graduates with a master's degree in computer science in 1999 averaged \$51,400.

According to Robert Half International, starting salaries in 1999 ranged from \$61,300 to \$88,000 for database administrators, from \$42,800 to \$59,800 for network administrators, and from \$27,000 to \$46,000 for help-desk support staff. Starting salaries in software development ranged from \$55,000 to \$80,000 for software engineers and from \$50,000 to \$65,000 for software installer/developers. Salaries for Internet-related occupations ranged from \$50,000 to \$73,800 for security administrators, \$51,500 to \$73,000 for webmasters, and from \$47,000 to \$65,500 for web developers.

Related Occupations

Other workers who use research, logic, and creativity to solve business problems are computer programmers, financial analysts, urban

planners, engineers, mathematicians, statisticians, operations research analysts, management analysts, and actuaries.

Sources of Additional Information

Further information about computer careers is available from:

☛ Association for Computing Machinery (ACM), 1515 Broadway, New York, NY 10036. Internet: <http://www.acm.org>

☛ Institute of Electrical and Electronics Engineers—United States of America, 1828 L Street, NW., Suite 1202, Washington, DC 20036. Internet: <http://www.ieee.org>

Information about becoming a Certified Computing Professional is available from:

☛ Institute for Certification of Computing Professionals (ICCP), 2200 East Devon Ave., Suite 268, Des Plaines, IL 60018. Internet: <http://www.iccp.org>

Information about becoming a Certified Quality Analyst is available from:

☛ Quality Assurance Institute, 7575 Dr. Phillips Blvd., Suite 350, Orlando, FL 32819. Internet: <http://www.qai.org>

Computer Programmers

(O*NET 25105)

Significant Points

- The level of education and experience required by employers has been rising, due to the increasing complexity of programming.
- A growing number of computer programmers are employed on a temporary or contract basis.
- Job prospects should be best for college graduates who are up to date with the latest skills and technologies.

Nature of the Work

Computer programmers write, test, and maintain the detailed instructions, called programs or software, that computers must follow to perform their functions. They also conceive, design, and test logical structures for solving problems by computer. Many technical innovations in programming—advanced computing technologies and sophisticated new languages and programming tools—have redefined the role of a programmer and elevated much of the programming work done today. As a result, it is becoming more difficult to distinguish different computer specialists—including programmers—since job titles shift so rapidly, reflecting new areas of specialization or changes in technology. Job titles and descriptions also may vary, depending on the organization. In this occupational statement, computer programmer refers to individuals whose main job function is programming; this group has a wide range of responsibilities and educational backgrounds.

Computer programs tell the computer what to do, such as which information to identify and access, how to process it, and what equipment to use. Programs vary widely depending upon the type of information to be accessed or generated. For example, the instructions involved in updating financial records are very different from those required to duplicate conditions on board an aircraft for pilots training in a flight simulator. Although simple programs can be written in a few hours, programs that use complex mathematical formulas, whose solutions can only be approximated, or that draw data from many existing systems, may require more than a year of work. In most cases, several programmers work together as a team under a senior programmer's supervision.

Programmers write specific programs by breaking down each step into a logical series of instructions the computer can follow. They then code these instructions in a conventional programming language, such as COBOL; an artificial intelligence language, such as

Prolog; or one of the most advanced function-oriented or object-oriented languages, such as Java, C++, or Visual Basic. Programmers usually know more than one programming language; and since many languages are similar, they can often learn new languages relatively easily. In practice, programmers are often referred to by the language they know, such as Java programmers, or the type of function they perform or environment in which they work, such as database programmers, mainframe programmers, or Internet programmers. In many large organizations, programmers follow descriptions that have been prepared by software engineers or systems analysts. These descriptions list the input required, the steps the computer must follow to process data, and the desired arrangement of the output.

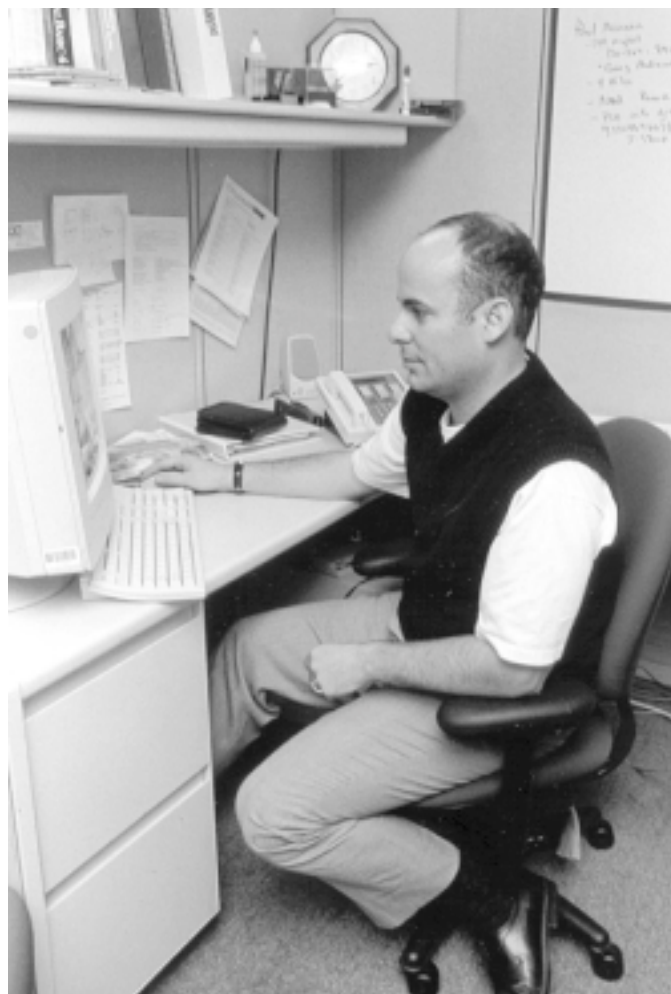
Many programmers are involved in updating, repairing, modifying and expanding existing programs. When making changes to a section of code, called a *routine*, programmers need to make other users aware of the task the routine is to perform. They do this by inserting comments in the coded instructions, so others can understand the program. Innovations such as computer-aided software engineering (CASE) tools enable a programmer to concentrate on writing the unique parts of the program, because the tools automate various pieces of the program being built. CASE tools generate whole sections of code automatically, rather than line by line. This also yields more reliable and consistent programs and increases programmers' productivity by eliminating some routine steps.

Programmers test a program by running it, to ensure the instructions are correct and it produces the desired information. If errors do occur, the programmer must make the appropriate change and recheck the program until it produces the correct results, a process called debugging. Programmers working in a mainframe environment may prepare instructions for a computer operator who will run the program. (A separate statement on computer operators appears elsewhere in the *Handbook*.) They may also contribute to a manual for users.

Programmers often are grouped into two broad types: applications programmers and systems programmers. *Applications programmers* usually focus on business, engineering, or science. They write software to handle a specific job, such as a program to track inventory, within an organization. They may also revise existing packaged software. *Systems programmers*, on the other hand, maintain and control computer systems software, such as operating systems, networked systems and database systems. These workers make changes in the sets of instructions that determine how the network, workstations, and central processing unit of the system handle the various jobs they have been given and how they communicate with peripheral equipment, such as terminals, printers, and disk drives. Because of their knowledge of the entire computer system, systems programmers often help applications programmers determine the source of problems that may occur with their programs.

Programmers in software development companies may work directly with experts from various fields to create software—either programs designed for specific clients or packaged software for general use—ranging from games and educational software to programs for desktop publishing, financial planning, and spreadsheets. Much of this type of programming is in the preparation of packaged software, which comprises one of the most rapidly growing segments of the computer services industry.

In some organizations, particularly small ones, workers commonly referred to as *programmer-analysts* are responsible for both the systems analysis and the actual programming work. (A more detailed description of the work of programmer-analysts is presented in the statement on computer systems analysts, engineers, and scientists elsewhere in the *Handbook*.) Advanced programming languages and new object-oriented programming capabilities are increasing the efficiency and productivity of both programmers and users. The transition from a mainframe environment to one that is primarily personal computer (PC) based has blurred the once rigid distinction between the programmer and the user. Increasingly, adept



Programmers must ensure that the program produces the correct results.

end-users are taking over many of the tasks previously performed by programmers. For example, the growing use of packaged software, like spreadsheet and database management software packages, allows users to write simple programs to access data and perform calculations.

Working Conditions

Programmers generally work in offices in comfortable surroundings. Many programmers may work long hours or weekends, to meet deadlines or fix critical problems that occur during off hours. Given the technology available, telecommuting is becoming common for a wide range of computer professionals—including computer programmers. Programmers can access a system from remote locations, to make corrections or fix problems.

Like other workers who spend long periods of time in front of a computer terminal typing at a keyboard, programmers are susceptible to eyestrain, back discomfort, and hand and wrist problems, such as carpal tunnel syndrome.

Employment

Computer programmers held about 648,000 jobs in 1998. Programmers are employed in almost every industry, but the largest concentration is in the computer and data processing services industry, which includes firms that write and sell software. Large numbers of programmers can also be found working for firms that provide engineering and management services, telecommunications companies, manufacturers of computer and office equipment, financial

institutions, insurance carriers, educational institutions, and government agencies.

A growing number of computer programmers are employed on a temporary or contract basis or work as independent consultants, as companies demand expertise with new programming languages or specialized areas of application. Rather than hiring programmers as permanent employees and then laying them off after a job is completed, employers can contract with temporary help agencies, consulting firms, or directly with programmers themselves. A marketing firm, for example, may only require the services of several programmers to write and debug the software necessary to get a new data base-management system running. This practice also enables companies to bring in people with a specific set of skills—usually in one of the latest technologies—as it applies to their business needs. Bringing in an independent contractor or consultant with a certain level of experience in a new or advanced programming language, for example, enables an establishment to complete a particular job without having to retrain existing workers. Such jobs may last anywhere from several weeks to a year or longer. There were 31,000 self-employed computer programmers in 1998, and this number is expected to increase.

Training, Other Qualifications, and Advancement

While there are many training paths available for programmers, mainly because employers' needs are so varied, the level of education and experience employers seek has been rising, due to the growing number of qualified applicants and the increasing complexity of some programming tasks. Bachelor's degrees are now commonly required, although some programmers may qualify for certain jobs with 2-year degrees or certificates. College graduates who are interested in changing careers or developing an area of expertise also may return to a 2-year community college or technical school for additional training. In the absence of a degree, substantial specialized experience or expertise may be needed. Even with a degree, employers appear to be placing more emphasis on previous experience, for all types of programmers.

Table 1. Highest level of school completed or degree received, computer programmers, 1998

	<i>Percent</i>
High school graduate or equivalent or less	10.6
Some college, no degree	20.5
Associate degree	10.2
Bachelor's degree	45.3
Graduate degree	13.4

About 3 out of 5 computer programmers had a bachelor's degree or higher in 1998 (see table 1). Of these, some hold a degree in computer science, mathematics, or information systems, whereas others have taken special courses in computer programming, to supplement their study in fields such as accounting, inventory control, or other areas of business. As the level of education and training required by employers continues to rise, this percentage should increase in the future.

Required skills vary from job to job, but the demand for various skills is generally driven by changes in technology. Employers using computers for scientific or engineering applications usually prefer college graduates who have degrees in computer or information science, mathematics, engineering, or the physical sciences. Graduate degrees in related fields are required for some jobs. Employers who use computers for business applications prefer to hire people who have had college courses in information systems (MIS) and business and who possess strong programming skills. Although knowledge of traditional languages is still important, increasing empha-

sis is placed on newer, object-oriented programming languages and tools, such as C++, Visual Basic, and Java. Additionally, employers are seeking persons familiar with fourth and fifth generation languages that involve graphic user interface (GUI) and systems programming. Employers also prefer applicants who have general business skills and experience related to the operations of the firm. Students can improve their employment prospects by participating in a college work-study program or by undertaking an internship.

Most systems programmers hold a 4-year degree in computer science. Extensive knowledge of a variety of operating systems is essential. This includes being able to configure an operating system to work with different types of hardware and adapting the operating system to best meet the needs of a particular organization. Programmers must also be able to work with database systems, such as DB2, Oracle, or Sybase, for example.

When hiring programmers, employers look for people with the necessary programming skills who can think logically and pay close attention to detail. The job calls for patience, persistence, and the ability to work on exacting analytical work, especially under pressure. Ingenuity and imagination are also particularly important, when programmers design solutions and test their work for potential failures. The ability to work with abstract concepts and to do technical analysis is especially important for systems programmers, because they work with the software that controls the computer's operation. Since programmers are expected to work in teams and interact directly with users, employers want programmers who are able to communicate with nontechnical personnel.

Entry-level or junior programmers may work alone on simple assignments after some initial instruction or on a team with more experienced programmers. Either way, beginning programmers generally must work under close supervision. Because technology changes so rapidly, programmers must continuously update their training, by taking courses sponsored by their employer or software vendors.

For skilled workers who keep up to date with the latest technology, the prospects for advancement are good. In large organizations, programmers may be promoted to lead programmer and be given supervisory responsibilities. Some applications programmers may move into systems programming after they gain experience and take courses in systems software. With general business experience, programmers may become programmer analysts or systems analysts or be promoted to a managerial position. Other programmers, with specialized knowledge and experience with a language or operating system, may work in research and development areas, such as multimedia or Internet technology. As employers increasingly contract out programming jobs, more opportunities should arise for experienced programmers with expertise in a specific area to work as consultants.

Technical or professional certification is a way to demonstrate a level of competency or quality. Product vendors or software firms also offer certification and may require professionals who work with their products to be certified. Many are widely sought and considered industry standards. Voluntary certification is also available through other organizations. Professional certification may provide a job seeker a competitive advantage.

Job Outlook

Employment of programmers is expected to grow faster than the average for all occupations through 2008. Jobs for both systems and applications programmers should be plentiful in data processing service firms, software houses, and computer consulting businesses. These types of establishments are part of computer and data processing services, which is projected to be the fastest growing industry in the economy. As organizations attempt to control costs and keep up with changing technology, they will maintain a need for programmers to assist in conversions to new computer languages and systems. In addition, numerous job openings will result from

the need to replace programmers who leave the labor force or transfer to other occupations such as manager or systems analyst.

Despite numerous openings, a number of factors will continue to moderate employment growth. The consolidation and centralization of systems and applications, developments in packaged software, advanced programming languages and tools, and the growing ability of users to design, write, and implement more of their own programs means more of the programming functions can be transferred to other types of workers. Furthermore, completion of Year 2000 work will mean that many programmers will need to be retrained and redeployed in other areas. And, as the level of technological innovation and sophistication increases, programmers should continue to face increasing competition from programming businesses overseas where much routine work can be outsourced at a lower cost.

Nevertheless, employers will continue to need programmers with strong technical skills who understand an employer's business and its programming needs. Given the importance of networking and the expansion of client/server environments, organizations will look for programmers who can support data communications and help implement electronic commerce and intranet strategies. Demand for programmers with strong object-oriented programming capabilities and technical specialization in areas such as client/server programming, multimedia technology, and graphic user interface (GUI), should arise from the expansion of intranets, extranets, and World Wide Web applications. Programmers will also be needed to create and maintain expert systems and embed these technologies in more and more products.

As programming tasks become increasingly sophisticated and an additional level of skill and experience is demanded by employers, graduates of 2-year programs and people with less than a 2-year degree or its equivalent in work experience should face strong competition for programming jobs. Competition for entry-level positions, however, can also affect applicants with a bachelor's degree. Prospects should be best for college graduates with knowledge of, and experience working with, a variety of programming languages and tools—including C++ and other object-oriented languages like Visual Basic and Java, as well as newer, domain-specific languages that apply to computer networking, data base management, and Internet application development. Because demand fluctuates with employers' needs, job seekers should keep up to date with the latest skills and technologies. Individuals who want to become programmers can enhance their prospects by combining the appropriate formal training with practical work experience.

Earnings

Median annual earnings of computer programmers were \$47,550 in 1998. The middle 50 percent earned between \$36,020 and \$70,610 a year. The lowest 10 percent earned less than \$27,670; the highest 10 percent earned more than \$88,730. Median annual earnings in the industries employing the largest numbers of computer programmers in 1997 were:

Personnel supply services	\$53,700
Computer and data processing services	48,900
Telephone communications	48,800
Professional and commercial equipment	47,700
Management and public relations	46,400

According to the National Association of Colleges and Employers, starting salary offers for graduates with a bachelor's degree in computer programming averaged about \$40,800 a year in 1999.

Programmers working in the West or Northeast earned somewhat more than those working in the South or Midwest. On average, systems programmers earn more than applications programmers.

According to Robert Half International, average annual starting salaries in 1999 ranged from \$38,000 to \$50,500 for applications development programmers and from \$49,000 to \$63,000 for systems programmers. Average starting salaries for Internet programmers ranged from \$48,800 to \$68,300.

Related Occupations

Other professional workers who must be detail-oriented include computer scientists, computer engineers, systems analysts, database administrators, statisticians, mathematicians, engineers, financial analysts, accountants, actuaries, and operations research analysts.

Sources of Additional Information

State employment service offices can provide information about job openings for computer programmers. Also check with your city's chamber of commerce for information on the area's largest employers.

For information about certification as a computing professional, contact:

☛ Institute for Certification of Computing Professionals (ICCP), 2200 East Devon Ave., Suite 268, Des Plaines, IL 60018. Internet: <http://www.iccp.org>

Further information about computer careers is available from:

☛ The Association for Computing Machinery (ACM), 1515 Broadway, New York, NY 10036. Internet: <http://www.acm.org>

☛ Institute of Electrical and Electronics Engineers—United States of America, 1828 L St. NW., Suite 1202, Washington, DC 20036. Internet: <http://www.ieee.org>

Mathematicians

(O*NET 25319A, 25319B, and 25319C)

Significant Points

- Employment is expected to decline because few mathematics graduates get jobs that have the title mathematician.
- Bachelor's and master's degree holders with extensive training in mathematics and a related discipline, such as computer science, economics, engineering, or operations research, should have good employment opportunities in related occupations.

Nature of the Work

Mathematics is one of the oldest and most fundamental sciences. Mathematicians use mathematical theory, computational techniques, algorithms, and the latest computer technology to solve economic, scientific, engineering, physics, and business problems. The work of mathematicians falls into two broad classes—theoretical (pure) mathematics and applied mathematics. These classes, however, are not sharply defined and often overlap.

Theoretical mathematicians advance mathematical knowledge by developing new principles and recognizing previously unknown relationships between existing principles of mathematics. Although they seek to increase basic knowledge without necessarily considering its practical use, such pure and abstract knowledge has been instrumental in producing or furthering many scientific and engineering achievements.

Applied mathematicians, on the other hand, use theories and techniques, such as mathematical modeling and computational methods, to formulate and solve practical problems in business, government, engineering, and the physical, life, and social sciences. For example, they may analyze the most efficient way to schedule airline routes between cities, the effect and safety of new drugs, the aerodynamic characteristics of an experimental automobile, or the cost effectiveness of alternate manufacturing processes for a businesses. Applied mathematicians working in industrial research and development may develop or enhance mathematical methods when solving a difficult problem. Some mathematicians, called cryptanalysts, analyze and decipher encryption systems designed to transmit military, political, financial, or law enforcement-related information in code.